



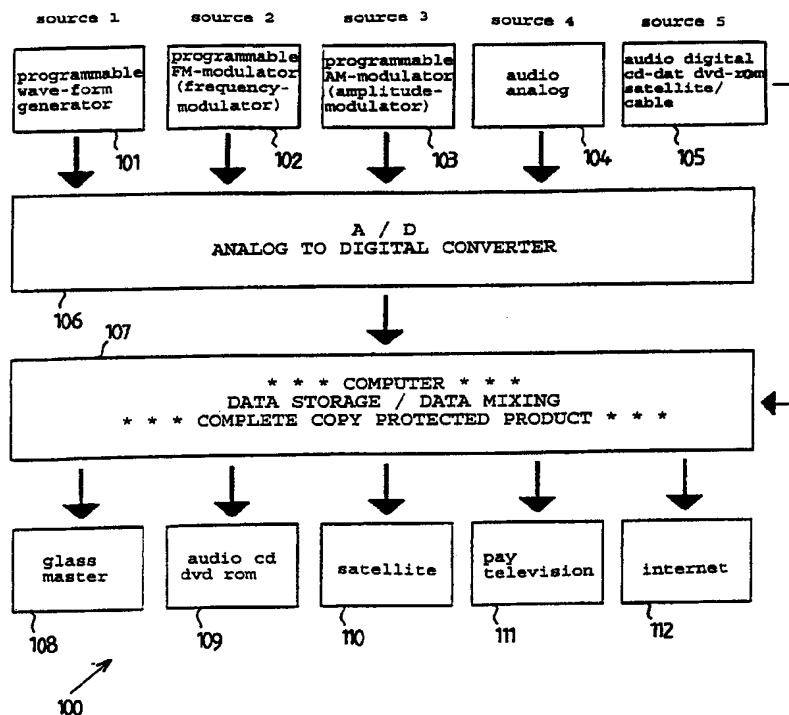
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : G11B 20/00		A2	(11) International Publication Number: WO 99/57723
			(43) International Publication Date: 11 November 1999 (11.11.99)
(21) International Application Number: PCT/EP99/03231		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).	
(22) International Filing Date: 4 May 1999 (04.05.99)			
(30) Priority Data: 98201432.6 4 May 1998 (04.05.98) EP 09/106,858 30 June 1998 (30.06.98) US			
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		Published Without international search report and to be republished upon receipt of that report.	

(54) Title: ANTI-COPYING METHODS AND DEVICES FOR DIGITAL INFORMATION SIGNALS

(57) Abstract

In order to protect audio signals against copying, it is proposed to mix the audio signal with at least one non-audible disturbance signal. A first disturbance signal may be a low-frequency signal which is added to the audio signal, while a second disturbance signal may be a high-frequency disturbance signal which is multiplied with the audio signal. Additionally, the second disturbance signal may be modulated by a modulating signal comprising either the original or inverted original signal, or spoken messages indicative of an illegal copy. Additionally, or alternatively, digital information may be copy protected by briefly interrupting the writing of the information to an information carrier. The latter measure is also effective for copy protecting software.



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Anti-copying methods and devices for digital information signals.

BACKGROUND OF THE INVENTION

The present invention relates to anti-copying methods and devices for audio and/or video signals, in particular digital audio signals, and for software information.

5 Present day digital techniques allow perfect copies of audio signals to be made. For example, the digital audio information of a compact disc (CD) can be digitally registered on tape or can even be used to physically reproduce the CD by means of a so-called CD burner (recorder for compact
10 discs). The possibility of digital copying, producing perfect copies of the original, has resulted in many illegal copies of CDs or other information carriers being made. This in turn leads to a substantial loss in copyright royalties. For this reason, there is a need for protection against copying of
15 audio signals.

The Prior Art offers several copy protection methods which all have drawbacks.

European Patent Application EP 0 298 691, for example, proposes to modulate an audio signal by an additional signal.
20 The degree of modulation is such that the modulation is not audible. Instead, a detector is used to detect the modulating signal. As in this known method the copy protection signal is not audible in the copy unless special equipment is used, its uselessness is severely limited.

25 European Patent Application EP 0 348 570 discloses a copy protection method in which an audible "spoiler signal" is added to the original audio signal. This has the disadvantage that the resulting audio signal is always distorted, even when played back by an authorized party.

30

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method for protecting audio signals against unauthorized

copying which does not suffer from the drawbacks of the Prior Art.

It is a further object of the present invention to provide a method for protecting audio signals which does not disturb the replay of those signals by authorized persons.

It is an additional object of the present invention to provide a method for protecting audio signals which does not require special equipment on the part of the user.

It is a yet further object of the present invention to provide devices for protectedly recording data carriers, as well as copy protected information carriers.

Accordingly, the present invention provides a method of protecting an audio signal against copying, the method comprising the step of mixing the audio signal with at least one non-audible disturbance signal which becomes audible upon copying the audio signal.

By mixing the audio signal with a non-audible disturbance signal, that is an additional signal having a frequency lying outside the normal audible range, it is possible to obtain a combined audio signal which is, when replayed as it is, effectively undisturbed but which shows audible disturbances when copied.

Advantageously, a first disturbance signal is a low-frequency signal which is added to the audio signal. When the original audio signal and the low-frequency first disturbance signal have comparable amplitudes, the resulting mixed output signal will be highly resistant against copying to an analogue tape recorder. This aspect of the present invention is based on the insight that slowly varying signals cause the magnetic heads of a tape recorder to effectively erase the recorded signal, or at least to suppress the recording of the signal.

Preferably, the low-frequency disturbance signal has a frequency of approximately 2 Hz, advantageously between 0.5 and 3 Hz, and has a substantially sinusoidal shape. These low frequencies are not audible, nor can they be reproduced by regular audio sets, yet they have the above-mentioned erasing effect.

Advantageously, a second disturbance signal is a high-frequency signal which is multiplied with the audio signal. This may effectively result in the original audio signal being substantially interrupted ("chopped") at a high
5 interruption frequency. Although this regular interruption is normally not audible due to the high (non-audible) frequency involved, copying of the signal will result in an incomplete demodulation of the combined signal due to the characteristics of the copying devices.

10 Preferably, the high-frequency disturbance signal has a frequency of approximately 20 kHz, and has a substantially sinusoidal shape, although other shapes such as block pulses are also possible.

Preferably, both the first, low-frequency disturbance
15 signal and the second, high-frequency disturbance signal are mixed with the original audio signal to produce a combined, copy-protected audio signal.

Advantageously, the audio signal is a digital signal representation involving a sampling frequency, and the second
20 disturbance signal has a frequency which varies in time, preferably from approximately half to approximately three quarters of the sampling frequency. This results in a second disturbance signal having both a varying (preferably increasing) frequency and, due to the aliasing effects
25 involved, a varying (preferably decreasing) amplitude. This results in a clearly audible amplitude modulation in the copied signal.

The second disturbance signal may also be frequency and/or amplitude modulated by auxiliary modulating signals,
30 e.g. derived from the original audio signal.

The invention further provides a device for protecting audio signals against copying, comprising signal generation means for generating at least one non-audible disturbance signal, mixing means for mixing at least one disturbance
35 signal with the audio signal, and output means for outputting the resulting mixed audio signal.

In accordance with a further aspect, the present invention provides a method of producing a copy-protected digital information carrier, comprising the step of recording

digital information on the carrier, characterized by interrupting the recording during short intervals.

BRIEF DESCRIPTION OF THE DRAWINGS

5 The present invention will be further explained with reference to the accompanying drawings, in which:

Fig. 1 schematically shows possible applications of the method of the present invention.

10 Fig. 2 schematically shows a first disturbance signal as used in the method of the present invention.

Fig. 3 schematically shows a combination of the first disturbance signal of Fig. 2 and an audio signal.

Fig. 4 schematically shows the signal of Fig. 3 as recorded on a tape recorder.

15 Fig. 5 schematically shows the low-frequency disturbance signal as in Fig. 2.

Fig. 6 schematically shows the low-frequency disturbance signal of Fig. 5, multiplied with a continuous high-frequency disturbance signal.

20 Fig. 7 schematically shows the low-frequency signal of Figs. 5, to which a continuous high-frequency signal is added.

Fig. 8 schematically shows a low-frequency disturbance signal combined with high-frequency bursts.

25 Fig. 9 schematically shows an alternative embodiment of the signal of Fig. 8.

Fig. 10 schematically shows a disturbance signal which is frequency and/or amplitude modulated.

30 Fig. 11 schematically shows the effect of applying the disturbance signal of Fig. 10 to an audio signal.

Fig. 12 schematically shows an original audio signal which is to be copy protected.

Fig. 13 schematically shows the signal of Fig. 12, multiplied with a high-frequency disturbance signal.

35 Fig. 14 schematically shows the signal of Fig. 13 after gain adjustment.

Fig. 15 schematically shows the signal of Fig. 14, compensated for gain adjustment.

Fig. 16 schematically shows a system for carrying out the method of the present invention.

Fig. 17 schematically shows a device for writing digital data to an information carrier in a copy-protected manner.

5

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

As shown in Figs. 1a and 1b, the copying of (digital) audio signals may be considered to involve two categories or groups of copying operations:

- 10 Group 1: from digital to analog signals, and
 Group 2: from digital to digital signals.

Although some of the techniques described in this document may also apply to copying from analog to analog signals (signal representations), the following discussion will focus
15 on the copying of digital audio signals, that is audio signals registered in a digital representation (sampled audio signals represented digitally by ones and zeros).

Especially group 2 (Fig. 1b) poses problems with respect to copyright, as the CD-burners and DAT-recorders normally
20 allow perfect copies of the original signals to be made (it will be understood that so-called DAT-recorders are tape/cassette recorders which digitally register audio signals on tape).

According to a first aspect of the present invention, a
25 low-frequency disturbance signal (also called first disturbance signal) is added to an (original) audio signal. Such a first disturbance signal is shown in Fig. 2. The signal has a frequency of approximately 2 Hz, although a range of frequencies from about 1 Hz to about 10 Hz may be
30 used. It is only desired that the first disturbance signal is normally not audible. The amplitude of the second disturbance signal is of the same order of magnitude as the amplitude of the audio signal it is to be added to, and is preferably two or three times as large as the latter. The first disturbance
35 signal is, like the second disturbance signal to be discussed later, preferably digitally generated.

The result of the adding of the signals is shown in Fig. 3. The mixed or combined signal of Fig. 3 is obtained by producing the sum of an original audio signal and the first

disturbance signal of Fig. 2. When this signal is reproduced from e.g. a CD (Compact Disc), the low-frequency modulation is not audible. However, when the combined signal of Fig. 3 is copied onto tape (regular tape or cassette), the slow
5 "shift" results in the recorded signal (shown in Fig. 4) being regularly interrupted. This is caused by the change in signal amplitude between the peaks and troughs of the first disturbance signal, which induces an erasing effect in the recorder heads. It will be clear that the resulting signal of
10 Fig. 4 has a very poor sound quality. The loss-less copying of the signal of Fig. 3 onto tape is thus effectively prevented by inducing a serious signal distortion.

According to a second aspect of the present invention, a second, high-frequency disturbance signal is applied to the
15 audio signal. Preferably, as shown in Figs. 5-9, this modulation is applied to the original audio signal through the first disturbance signal, but the second disturbance signal may also be applied independently from, or even without, the first disturbance signal.

20 Fig. 5 again shows the first disturbance signal of Fig. 2. This low-frequency signal is mixed with a high-frequency second disturbance signal which preferably is a sine wave. This second disturbance signal preferably has an frequency of approximately 20 kHz, but may also have a varying frequency,
25 as will be explained later. The frequency is chosen such that the second disturbance signal, like the first disturbance signal, is normally non-audible.

The signal of Fig. 6 is the resulting signal after multiplying the first disturbance signal of Fig. 5 with the
30 second disturbance signal (product of the signal amplitudes). The signal of Fig. 7 is the resulting signal after adding the first disturbance signal of Fig. 5 to the second disturbance signal (sum of the signal amplitudes).

The signal of Fig. 8 consists of a low-frequency first
35 disturbance signal combined with bursts of a high-frequency second disturbance signal (the bursts are schematically represented in Figs. 8 and 9 by shaded areas). These bursts preferably have a duration of about 50 to 200 ms and do preferably occur about the point where the first disturbance

signal is "zero" (average signal value). By using a discontinuous second disturbance signal, instead of the continuous second disturbance signal of Figs. 6 and 7, a first disturbance signal having a much smaller amplitude can be used to obtain identical results. Thus, using a burst-like second disturbance signal makes it possible to reduce the energy of the first disturbance signal.

The high-frequency bursts are even more effective when they occur in pairs, as schematically represented in Fig. 9. In the exemplary signal of Fig. 9, two high-frequency bursts (schematically represented as shaded areas) are located just before and just after each "zero" crossing of the low-frequency disturbance signal. It has proven less effective to locate the bursts around the peaks and troughs of the low-frequency signal. The paired bursts of Fig. 9 also allow a reduced low-frequency signal amplitude.

Instead of using bursts, the disturbance signal or signals may be applied intermittently. That is, the first and/or second disturbance signals may be mixed with the original audio signal only in certain time periods of e.g. 0.1 s or 1.0 s. These time periods are spaced apart at a distance of e.g. also 0.1 s or 1.0 s. The resulting audio signal comprises alternating processed and unprocessed periods. As a result, the eventual disturbance when the signal is copied is much more pronounced.

The heads of a tape (or cassette) recorder normally do not reproduce signals having a frequency of about 20 kHz. Feeding the signal of any of the Figs. 6-9 to the recording head of a tape recorder will result in a partial demodulation of the high-frequency disturbance signal. This partial demodulation will lead to a distortion of the signal, thus effectively protecting the signal against copying.

It will be understood that the copy protection of the present invention does not affect the bias frequency of tape or cassette recorders. Instead, the audio signal to be recorded is affected in such a way, that due to the properties of the recorder the previously inaudible disturbances become audible.

Advantageously, the high-frequency second disturbance signal is frequency modulated by at least one modulating signal. Alternatively, or additionally, the second disturbance signal is amplitude modulated by the at least one modulating signal. These modulations will result in a further distortion of the (partially) demodulated signal.

The modulating signal may contain spoken messages indicative of illegal copying, such as "this is an illegal copy" or "this recording is copy protected". The modulating signal may also be derived from the original audio signal and may comprise the original signal itself or its inverse (inverted original signal). Preferably, the modulating signal contains both spoken messages, the original signal and the inverted original signal, each during a certain time period of for example 30 seconds.

In order to produce a copy-protected recording, the modulating signals may be additionally registered on the information carrier (such as a CD) or may be transmitted separately via a satellite network, internet, or the like.

The disturbance signals described above are in particular suited for the prevention of copying without quality loss to analog recorders (group 1 in Fig. 1). The (second) disturbance signal of Fig. 10 is in particular suited for the prevention of copying without quality loss to digital recorders, such as so-called CD burners.

The disturbance signal of Fig. 10 has a frequency which increases stepwise from 20 kHz to 30 kHz. As the sampling frequency used for CD recordings is about 44 kHz, the disturbance signal of Fig. 10 increases in frequency from just below half the sampling frequency (the Shannon frequency) to about three-quarters of the sampling frequency. As the frequency increases, the amplitude of the signal decreases. This type of signal proves to be highly effective in the prevention of loss-less copying. When mixed with an audio signal (by multiplying or adding), the signal of Fig. 11 results. As shown in Fig. 11, the resulting signal has a decreasing amplitude (schematically represented by the drawn lines A), effected by the modulating signal. In the signal of

Fig. 11, the amplitude variations caused by the frequency sweep are clearly audible.

In addition to the frequency sweep, the same modulating signals may be used to modulate the second disturbance signals of Fig. 10 as used for the second disturbance signal of Figs. 6-9. Thus spoken messages, the original signal and/or the inverted original signal may be used to further modulate the signal of Fig. 10.

The audio signal fragment shown in Fig. 12 has three peaks (maxima) and three troughs (minima). The peaks M1 and M3 have relative (positive) signal amplitudes of 30% and 25% respectively. The troughs M2 and M4 have relative (negative) signal amplitudes of 50% and 35% respectively.

In accordance with the present invention, the signal of Fig. 12 is combined (multiplied) with a high-frequency disturbance signal. The resulting combined signal is shown in Fig. 13. Due to the disturbance signal, the audio signal is "chopped". As a result, the energy content of the combined signal is only half of that of the original signal. When such a signal is reproduced, the volume (sound level) is also only half of that of the original signal. In order to compensate for this, the amplitude of the signal may be doubled, as shown in Fig. 14. This doubled signal has the same energy content as the original signal and will therefore, when reproduced, generate the same sound volume.

To achieve an even better level of copy protection, the maximum amplitude of the "chopped" signal sections may not be just doubled, but may be raised to approximately the highest possible level. Thus, all signal samples in a certain signal section (e.g. section S1) are multiplied by a factor k which is chosen such that the maximum amplitude (M1) equals 90% or 95% of the highest possible signal level (100% is also possible but creates the risk of irreversible signal distortion). It will be understood that for each signal section a different factor k applies. Preferably, k is greater than or equal to one.

The signal distortion introduced by multiplying the signal samples by a factor k is compensated for by introducing samples having a signal amplitude with a reverse

polarity. Thus, where the multiplication by k results in signal amplitudes $k.v$, v being the original amplitude, an additional sample having an amplitude $v' = -(k-1).v$ will result in an unaltered signal level when played back.

5 However, due to the changed signal structure, copying of the thus processed signal will result in distortions.

The system 100 shown by way of example in Fig. 16 is designed for copy protecting audio signals in accordance with the present invention. The system comprises signal sources
10 101-105, an analog to digital convertor 106, a signal processing unit (computer) 107 and signal destinations 108-112. The sources 101-104 of analog signals are connected to the signal processing unit 107 via the A/D converter 106, while the digital source 105 (e.g. a CD player) is directly
15 connected with the signal processing unit 107.

The first source 101 is a programmable wave-form generator for producing the first and/or second disturbance signal. The second and third sources 102 and 103 are programmable FM and AM modulators respectively. The fourth
20 source 104 is an analog audio source, e.g. for producing spoken messages. The sources 101-104 may be constituted by software, advantageously stand-alone software. Thus all signal manipulations take place in the digital domain.

By means of the system 100, the method of the present
25 invention may be readily applied.

An audio signal which has been combined with the disturbance signals according to the present invention may be stored on a commercially available information carrier, such as a floppy disc having a magnetic recording medium, or a CD
30 having an optical recording medium.

In accordance with another aspect of the present invention an additional or alternative form of copy protection is achieved by modifying the registration of digital information on a digital information carrier. In the
35 case of a CD, the digital information is recorded on the CD's surface by making a track of small holes in the surface using a laser beam (the so-called "burning" of the CD). It has been found that briefly interrupting the laser beam, resulting in a number of holes not being made, provides a very effective

copy protection. That is, the CD thus protected may be played normally, resulting in no signal distortion at all, provided the interruptions in the track are short enough. However, when the contents (the signal) of the CD are copied to e.g. a hard disc, the resulting digital information is distorted to the point of being useless.

The interruption of the recording or "burning" process of audio CDs can be effected in several ways:

- short interruptions during pauses, at the beginning and/or the end of the CD and/or between music pieces; and/or
- short interruptions at the zero crossings of the audio signals; and/or
- very short interruptions, e.g. of about $1\mu\text{s}$ or even 1 ns (nano-second), having a repetition frequency lying above the audible range, or even above the sampling rate used.

In the case of video recordings, short interruptions may be effected at the edges of the video image, that is, outside the visible image. Short interruptions may also be used to copy protect software programs recorded on e.g. CD-ROMs. In the latter case, pauses (interruptions) can be created in the software program in order to create "blank spots". This causes uncontrollable digital information inserted in the original software information after coping to e.g. hard disc and/or CD ("on the fly"). In this particular case, the frequency of the interruptions may lie within the audible range.

The arrangement of Fig. 17 comprises a laser section 201, a power supply 202 and data circuits 203 of a CD recorder. The data circuits 203 provide a digital data stream representing data to be recorded. Accordingly, the laser of laser section 201 is modulated by the data stream when burning (making small holes in) CD 210. During the burning process, the CD is rotated by rotation means (not shown). Power supply 202 continuously provides power to the laser section 201.

According to the present invention an additional circuit 204 is provided which briefly interrupts the laser, e.g. by briefly interrupting the power supplied to it. To this end,

the interruption circuit 204 may be programmed to cause interruptions on a regular basis or at predetermined moments in time. Alternatively, or additionally, the data stream originating from circuits 203 may be fed to the interruption circuit 204 to effect data-dependent interruptions. The latter option enables the interruptions to occur e.g. during pauses or at zero crossings of the audio or video signal. Thus a very effective supplementary copy protection may be attached, which may also be used without combining the original signal with non-audible disturbance signals.

Instead of using an additional interruption circuit 204, the hardware and/or software of data circuits 203 may be modified so as to cause interruptions in the laser beam.

Although the invention has been described primarily with reference to audio signals, it will be understood that its principles can be applied to other signals as well, e.g. video signals, by mixing normally non-perceivable disturbance signals with the original signal.

It will thus be understood by those skilled in the art that the present invention is not limited to the embodiments discussed above and that many additions and modifications are possible without departing from the scope of the present invention.

CLAIMS:

1. A method of protecting an audio signal against copying, the method comprising the step of mixing the audio signal with at least one non-audible disturbance signal which becomes audible upon copying the audio signal.

5

2. The method according to claim 1, wherein a first disturbance signal is a low-frequency signal which is added to the audio signal, the low-frequency disturbance signal preferably having a frequency of approximately 2 Hz.

10

3. The method according to claim 1 or 2, wherein a second disturbance signal is a high-frequency signal which is multiplied with the audio signal, the high-frequency disturbance signal having a frequency of approximately 20 kHz.

15

4. The method according to claim 3, wherein the audio signal is a digital signal representation involving a sampling frequency, and wherein the second disturbance signal has a frequency which varies in time, preferably from approximately half to approximately three quarters of the sampling frequency.

20

5. The method according to claim 3, wherein the second disturbance signal is modulated by a modulating signal, said modulating signal comprising either alone or in combination:

25

- spoken messages,
- the original audio signal,
- the inverted original audio signal.

30

6. The method according to claim 5, wherein the second disturbance signal is frequency modulated by the modulating signal.

35

7. The method according to claim 5, wherein the second disturbance signal is amplitude modulated by the modulating signal.

8. An information carrier comprising a recording medium storing an audio signal which is copy protected by mixing the audio signal prior to the storing with at least one non-audible disturbance signal which becomes audible upon copying the audio signal.

9. A device for protecting audio signals against copying, the device comprising signal generation means for generating at least one non-audible disturbance signal, mixing means for mixing the at least one disturbance signal with the audio signal, and output means for outputting the resulting mixed audio signal.

10. The device according to claim 9, wherein the mixing means comprise adding means.

11. The device according to claim 9, wherein the mixing means comprise multiplication means.

12. The device according to claim 9, wherein the signal generation means are arranged for generating a first, low-frequency disturbance signal which is added to the audio signal, the low-frequency disturbance signal preferably having a frequency of approximately 2 Hz.

13. The device according to claim 9, wherein the signal generation means are arranged for generating a second, high-frequency disturbance signal which is multiplied with the audio signal, the high-frequency disturbance signal having a frequency of approximately 20 kHz.

14. The device according to claim 13, the device being arranged for copy protecting an audio signal which is a digital signal representation involving a sampling frequency, and wherein the signal generating means are arranged for generating a second disturbance signal having a frequency which varies in time, preferably from approximately half to approximately three quarters of the sampling frequency.

15. The device according to claim 13, wherein the mixing means are arranged for modulating the second disturbance signal by a modulating signal, said modulating signal comprising either alone or in combination:

- 5 - spoken messages,
 - the original audio signal,
 - the inverted original audio signal.

16. The device according to claim 15, wherein the mixing
10 means are arranged for frequency modulating the second disturbance signal by the modulating signal.

17. The device according to claim 15, wherein the mixing
15 means are arranged for amplitude modulating the second disturbance signal by the modulating signal.

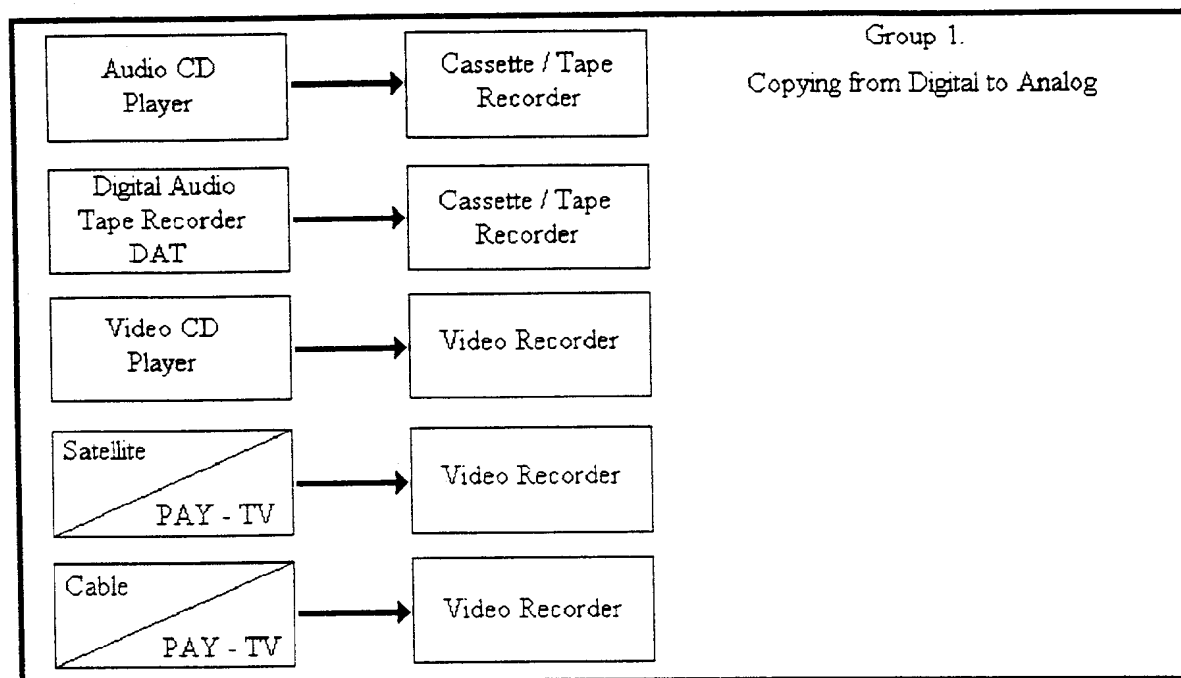
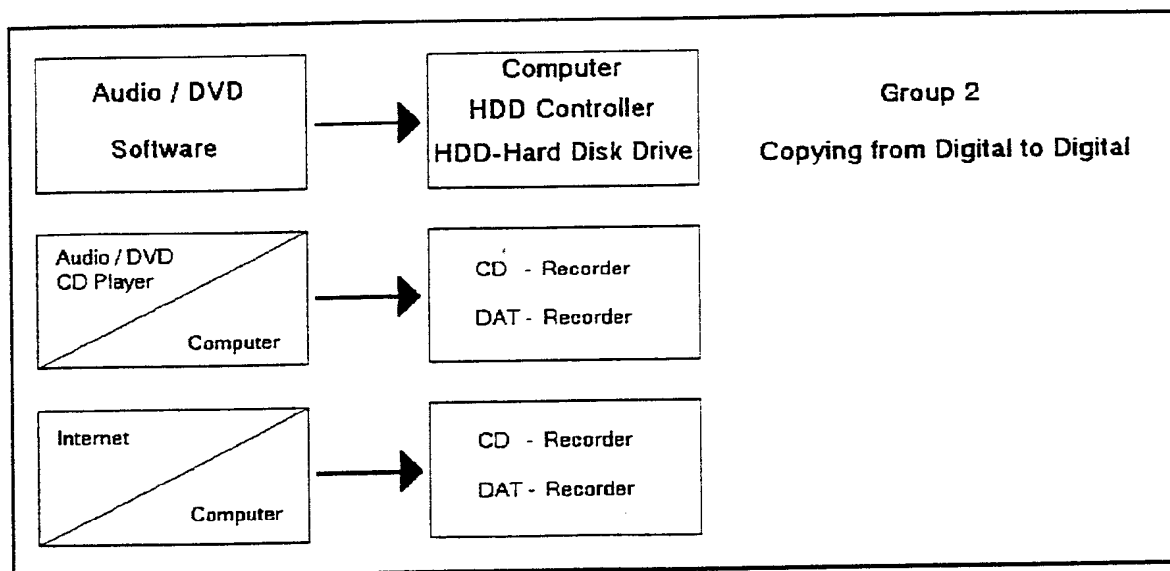
18. A method of producing a copy-protected digital
information carrier, comprising the step of recording digital
information on the carrier (210), **characterized** by
20 interrupting the recording during short intervals.

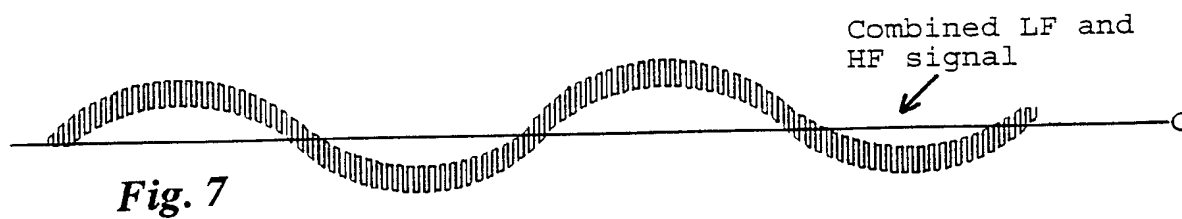
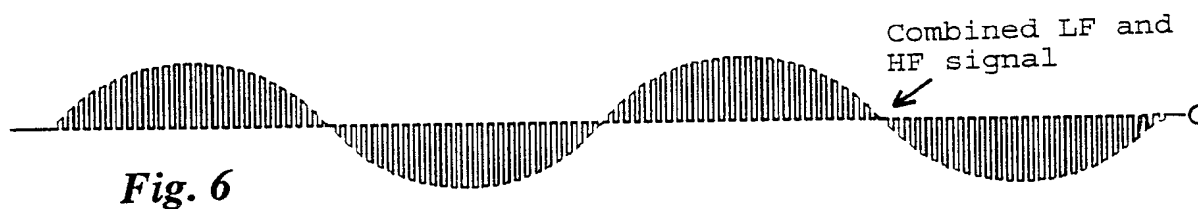
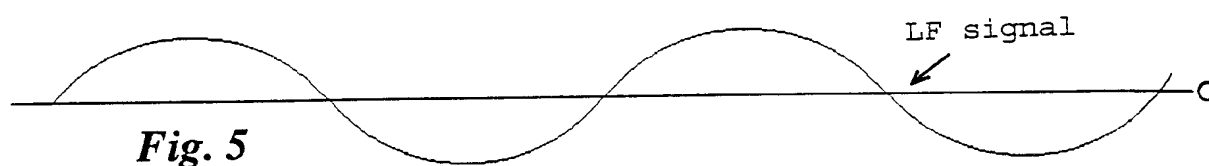
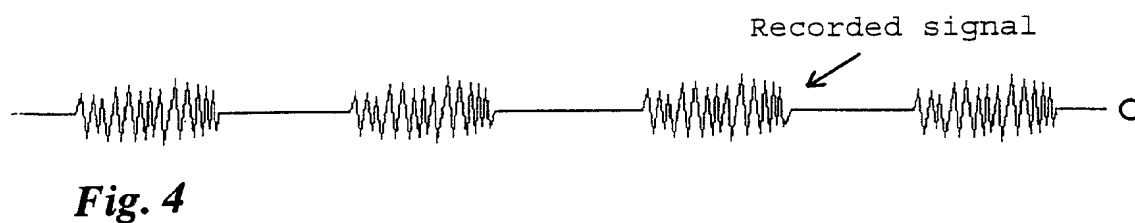
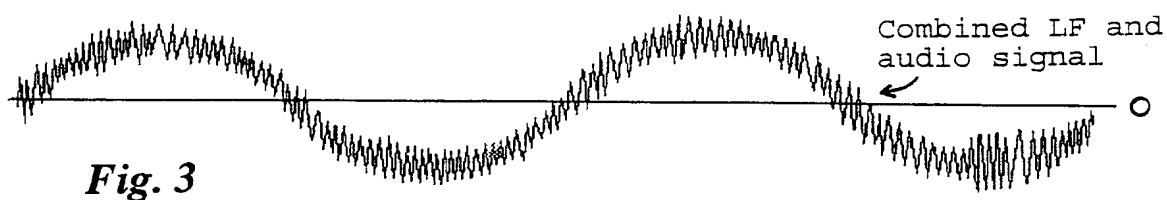
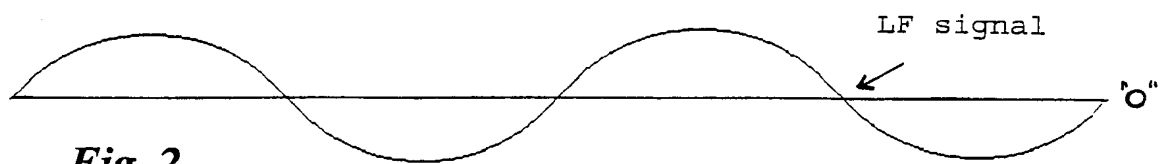
19. A device for applying the method of claim 18.

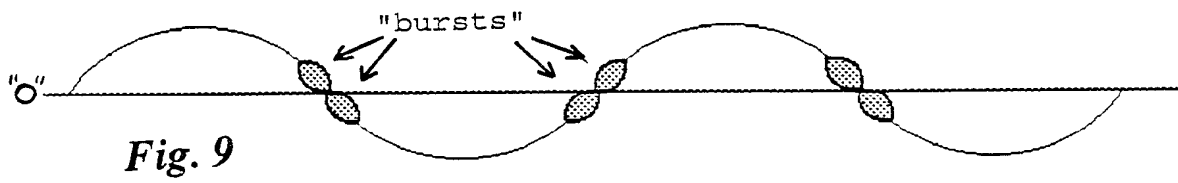
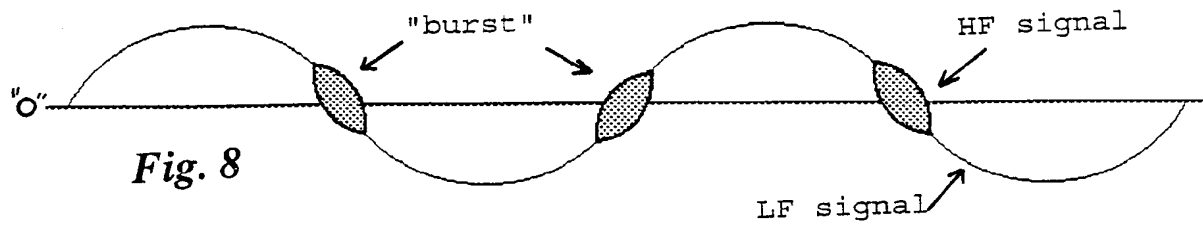
20. An information carrier, provided with a track of marks
25 representing digital information, the tracks being interrupted over short distances to provide copy protection.

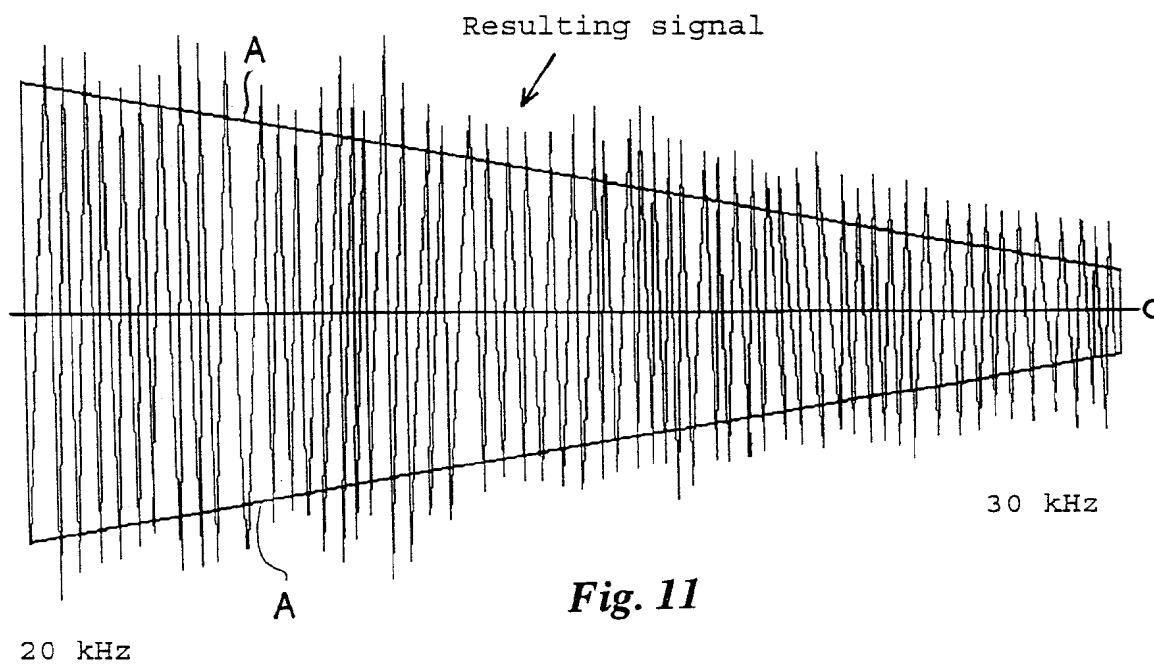
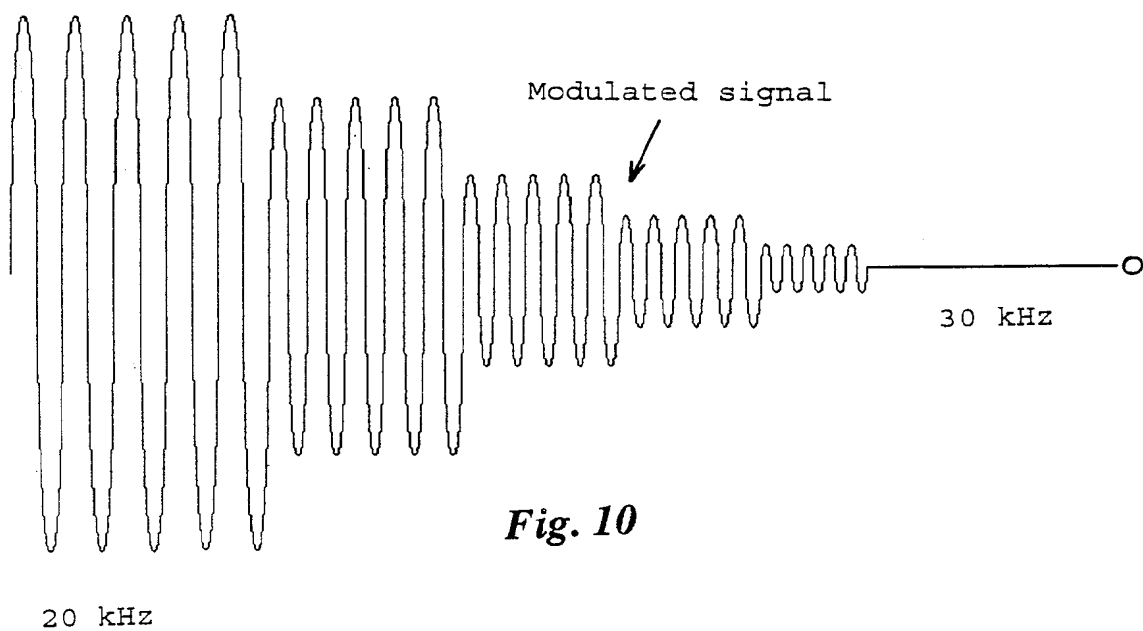
21. The information carrier according to claim 20, wherein
the short distances correspond to playing times between 100
30 μ s and 1 ns.

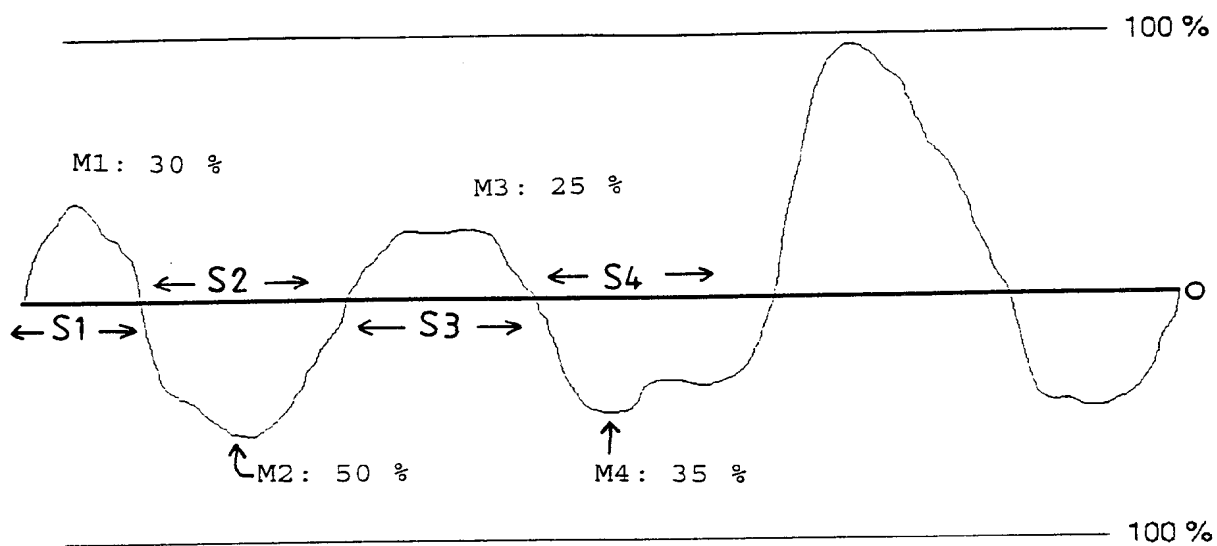
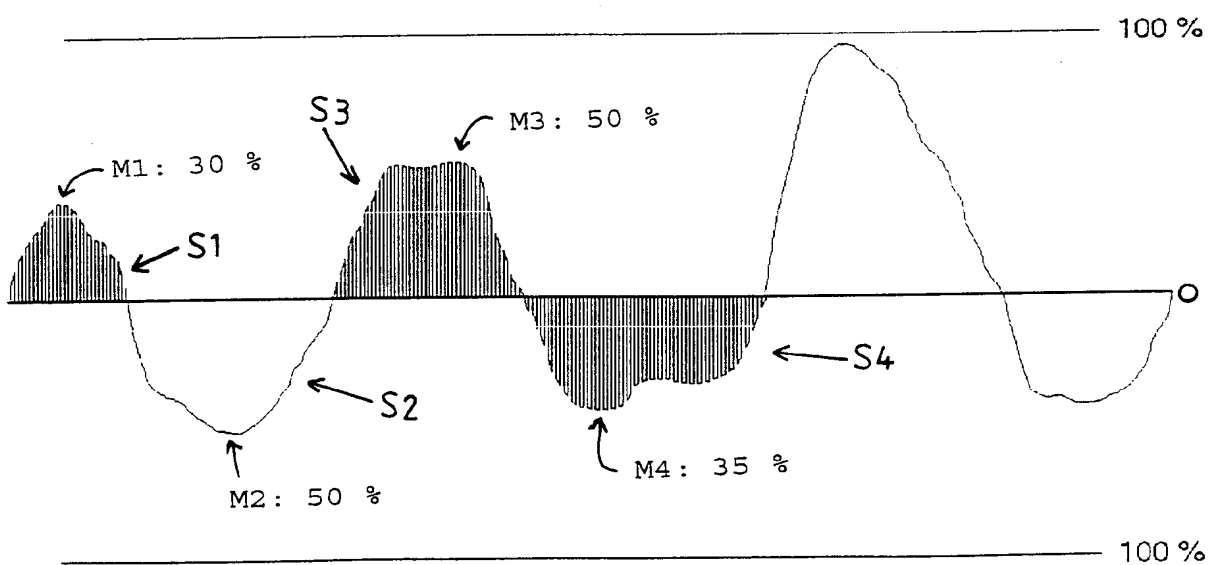
(86)

*Fig. 1a**Fig. 1b*







**Fig. 12****Fig. 13**

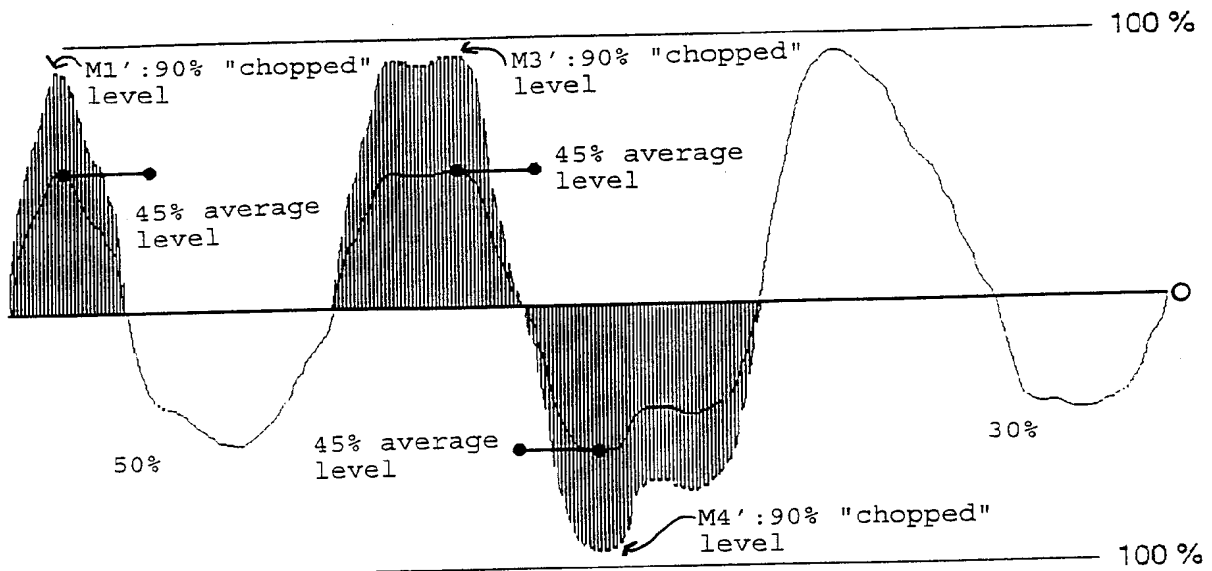


Fig. 14

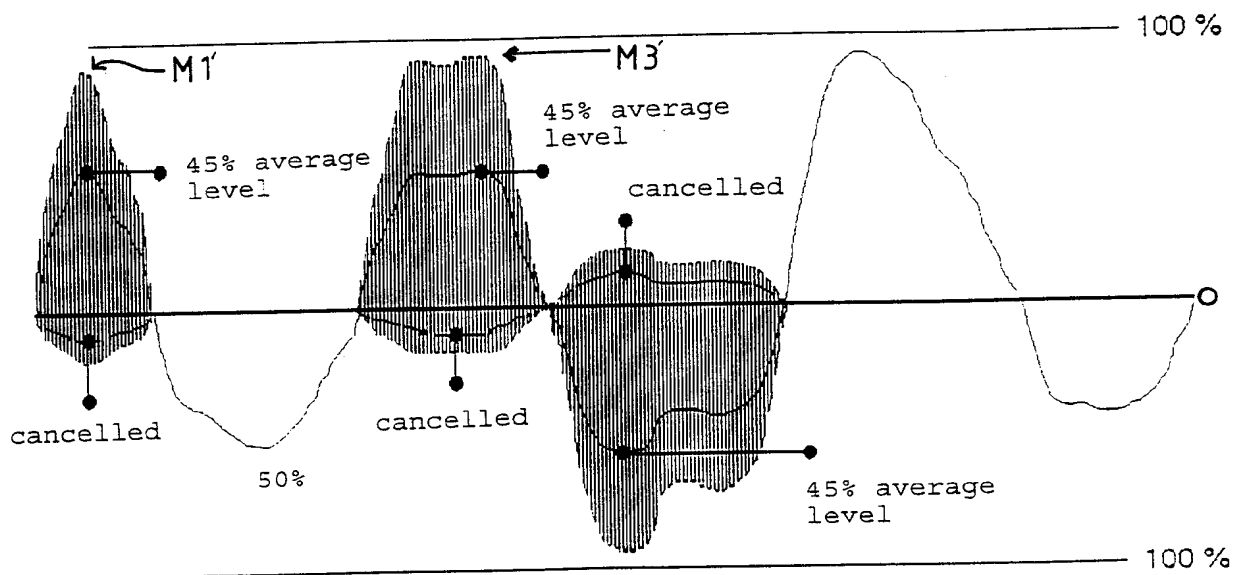
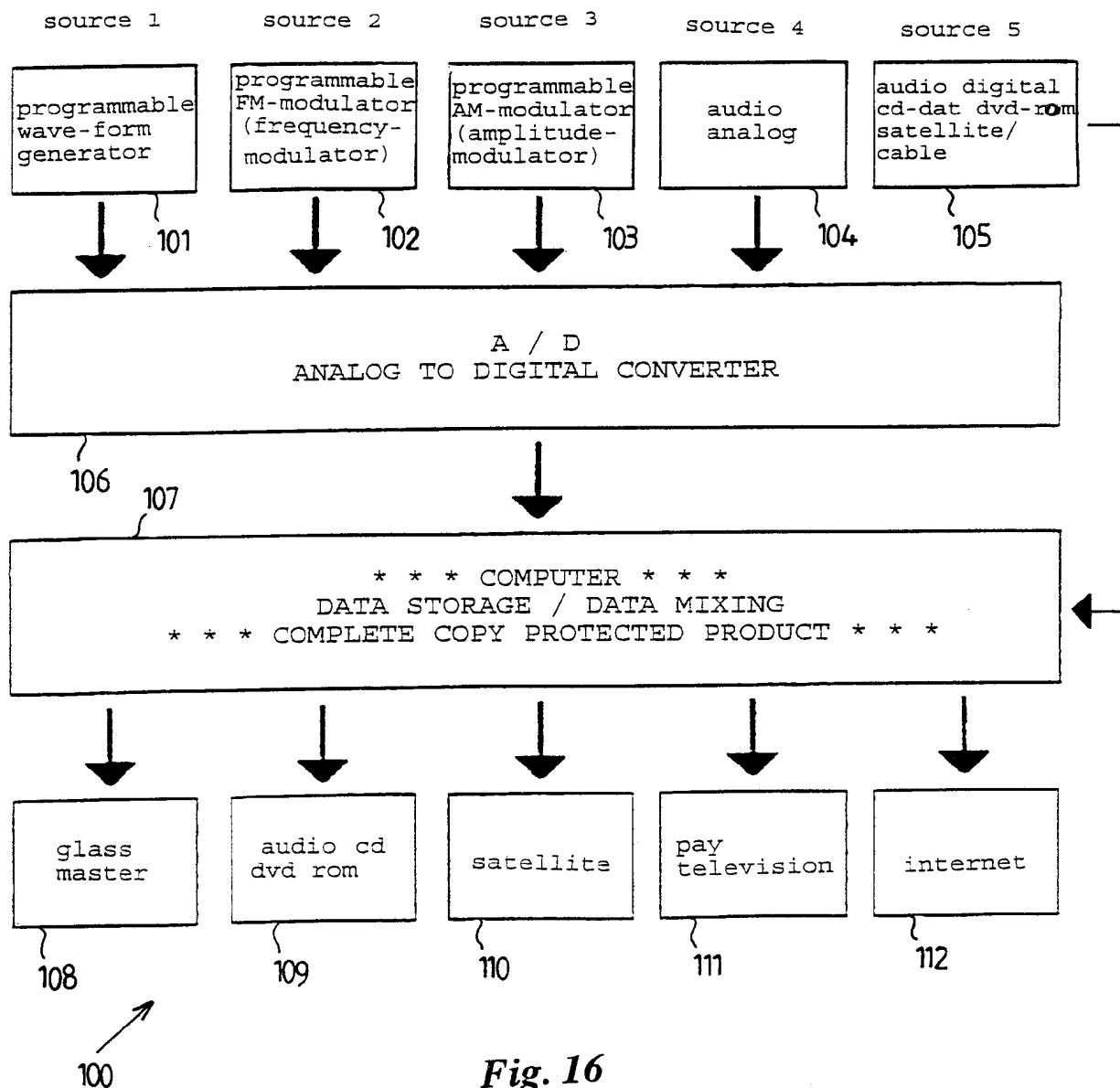
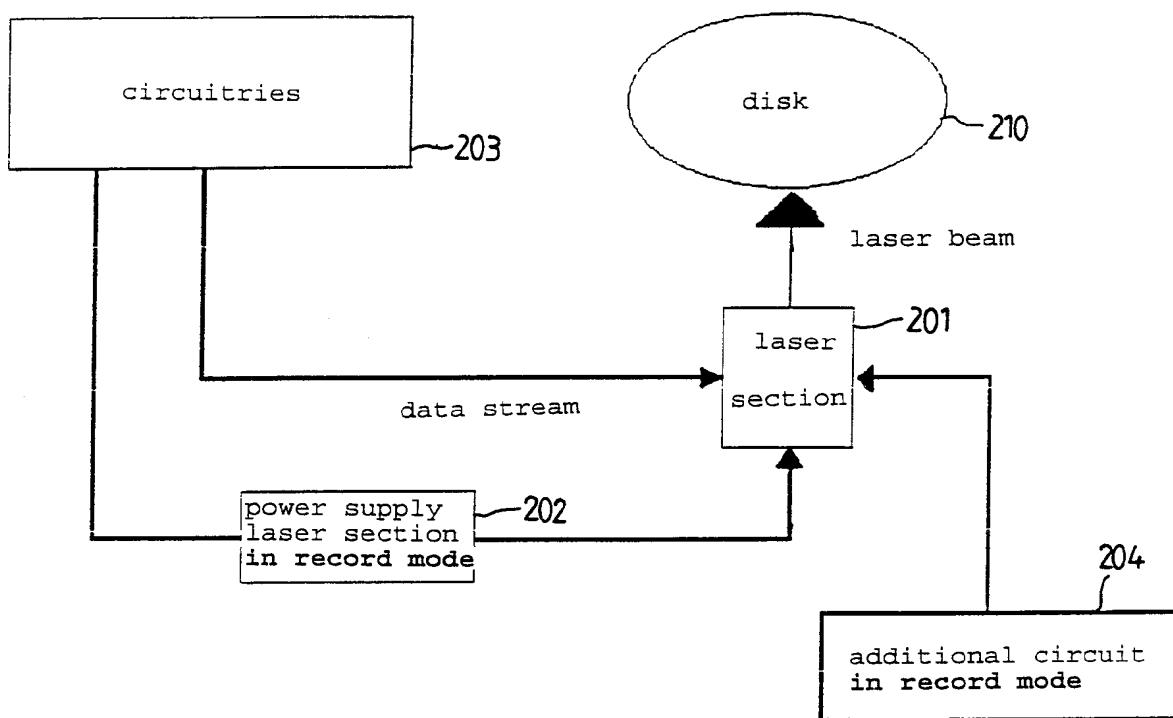


Fig. 15

*Fig. 16*

*Fig. 17*